Federal Communications Commission
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Laboratory Division

SAR Test Considerations for LTE Handsets and Data Modems

This document provides SAR test guidance for devices incorporating Long Term Evolution (LTE) capabilities. The procedures are compiled based on recent inquiries from grantees and test laboratories on how to test USB dongles and wireless handsets with LTE functions. As device implementations continue to emerge, further revisions to the SAR test requirements for LTE products may be necessary. These test considerations have taken into account the different factors and parameters, due to evolving designs, which could result in varying test configurations required to support RF exposure compliance. Some of the factors are related to variations in maximum output power for different number of resource blocks (RB) allocated within the channel bandwidth frequency. There are issues concerning the test setups required for handsets using fixed or dynamic power reduction schemes to satisfy SAR compliance in simultaneous voice and data modes. The other concerns are mostly associated with SAR system implementation differences for simultaneous transmission measurements and how to apply test reduction to complex operating combinations without compromising compliance. The procedures in this document are required for a TCB to approve LTE devices. The use of procedures other than those provided in this document require the applications to be submitted directly to the FCC for approval.

For products that apply power reduction to manage the maximum output power of selected operating modes to satisfy SAR compliance, other equipment certification or operating requirements, details of the power reduction implementations are necessary to determine SAR test requirements for the antenna configurations and simultaneous transmission conditions. The Permit But Ask (PBA) procedure in KDB 388624 is required for a TCB to approve devices that require SAR to be measured in a power reduction mode. The PBA procedure is also required for devices incorporating LTE functions or requiring simultaneous transmission SAR measurement to demonstrate RF exposure compliance. While it is not mandatory for test laboratories to submit KDB inquiries for these, it is recommended that a KDB inquiry be submitted to confirm that the SAR test setups and methodologies used are acceptable for testing the power reduction and simultaneous transmission conditions to avoid unnecessary delays during the final TCB approval stage.

The procedures and considerations included in the Appendix are applicable for testing USB dongles and wireless handsets incorporating LTE functions. A KDB inquiry must be submitted to seek test guidance for products and circumstances where this document is insufficient to address the SAR test concerns.

Appendix

Identifying the wireless operating configurations and parameters for submitting a laboratory testing KDB inquiry, a TCB PBA or preparing SAR reports:

1) identify the operating frequency range of each LTE transmission band used by the device
2) identify the channel bandwidths used in each frequency band; 1.4, 3, 5, 10, 15, 20 MHz etc
3) identify the high, middle and low (H, M, L) channel numbers and frequencies in each LTE frequency band[1]
4) specify the UE category and uplink modulations used
5) include descriptions of the LTE transmitter and antenna implementation; and also identify whether it is a standalone transmitter operating independently of other wireless transmitters in the device or sharing hardware components and/or antenna(s) with other transmitters etc
6) identify the LTE voice/data requirements in each operating mode and exposure condition with respect to head and body test configurations, antenna locations, handset flip-cover or slide positions, antenna diversity conditions etc
7) identify if Maximum Power Reduction (MPR) is optional or mandatory, i.e. built-in by design:
    a) only mandatory MPR may be considered during SAR testing, when the maximum output power is permanently limited by the MPR implemented within the UE; and only for the applicable RB (resource block) configurations specified in LTE standards
    b) A-MPR (additional MPR) must be disabled
8) include the maximum average conducted output power measured on the required test channels for each channel bandwidth and UL modulation used in each frequency band:
    a) with 1 RB allocated at the upper edge of a channel
    b) with 1 RB allocated at the lower edge of a channel
    c) using 50% RB allocation centered within a channel
    d) using 100% RB allocation
9) identify all other U.S. wireless operating modes (3G, Wi-Fi, WiMax, Bluetooth etc), device/exposure configurations (head and body, antenna and handset flip-cover or slide positions, antenna diversity conditions etc.) and frequency bands used for these modes
10) include the maximum average conducted output power measured for the other wireless modes and frequency bands

[1] For LTE bands that do not support at least 3 channels in certain channel bandwidths, test the available channels instead. Also see channel selection considerations in KDB 447498.

11) identify the simultaneous transmission conditions for the voice and data configurations supported by all wireless modes, device configurations and frequency bands, for the head and body exposure conditions and device operating configurations (handset flip or cover positions, antenna diversity conditions etc.)

12) when power reduction is applied to certain wireless modes to satisfy SAR compliance for simultaneous transmission conditions, other equipment certification or operating requirements, include the maximum average conducted output power measured in each power reduction mode applicable to the simultaneous voice/data transmission configurations for such wireless configurations and frequency bands; and also include details of the power reduction implementation and measurement setup

13) include descriptions of the test equipment, test software, built-in test firmware etc. required to support testing the device when power reduction is applied to one or more transmitters/antennas for simultaneous voice/data transmission

14) when appropriate, include a SAR test plan proposal with respect to the above

15) if applicable, include preliminary SAR test data and/or supporting information in laboratory testing inquiries to address specific issues and concerns or for requesting further test reduction considerations appropriate for the device; for example, simultaneous transmission configurations

Typical head SAR test considerations for LTE voice calls without simultaneous transmission:

This will be addressed when voice calls, with respect to VOIP requirements, are considered for LTE handsets.

Typical head and body SAR test considerations for LTE data mode only without simultaneous transmission:

1) The procedures shall be applied independently to the *device and exposure configurations* required for head & body, handset flip or slide positions, USB dongle orientations and antenna diversity conditions etc.; for example, in the touch and tilt positions for head, according to the supplied body-worn accessories and an acceptable body-worn test separation distance applicable to the accessories typically available for the handset or applying the test positions in KDB 447498 for USB dongles.

2) When MPR is implemented permanently within the UE, regardless of network requirements, only those RB configurations allowed (see 3GPP standards) for the channel bandwidth and modulation combinations may be tested with MPR. Configurations with RB allocations below the required RB thresholds must be tested without MPR. A-MPR must always be disabled.

3) For each LTE frequency band:

A) Begin by measuring SAR on the high, middle and low (H, M, L) channels[2] using the largest channel bandwidth[3], in QPSK with 50% RB allocation[4] centered within the channel bandwidth.[5]

I) When the SAR of a channel measured in A) is > 1.45 W/kg, also measure SAR for that channel using QPSK with 100% RB allocation.

a) If the highest SAR measured in I) is > 1.45 W/kg, measure SAR on all channels (H, M, L).

B) Measure SAR in QPSK with 1 RB allocated at the high end of the channel edge using the highest SAR channel measured in A); and then repeat the measurement at the low end of the channel edge.[6]

I) If the SAR measured for a 1 RB configuration in B) is > 1.45 W/kg, test that 1 RB configuration on all channels (H, M, L).

4) For the largest channel bandwidth in each LTE frequency band[7]:

A) Measure SAR in 16QAM with 50% RB allocation using the highest SAR channel measured in 3) A).[8]

I) When the SAR measured in A) is > 1.45 W/kg:

a) measure SAR on all channels (H, M, L), and

b) also measure SAR for the channel in A) using 16QAM with 100% RB allocation

i) If the highest SAR measured in b) is > 1.45 W/kg, measure SAR on all channels (H, M, L).

B) Measure SAR in 16QAM with 1 RB allocated at the high end of the channel edge using the SAR channel measured in A); and then repeat the measurement at the low end of the channel edge.[9]

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[2] When the maximum output power variation across H, M and L channels is ≤ ½ dB, start with the middle channel; otherwise, start with the highest output power channel. When the measured 1-g SAR for the middle or highest output power channel is ≤ 0.8 W/kg, testing of the remaining two channels in that device and exposure configuration is not necessary. Also see footnote 1.

[3] Test the largest channel bandwidth, among 1.4, 3, 5, 10, 15 and 20 MHz, used by the device. Spectrum plots should be used to demonstrate the tested RB allocations have been established correctly at the maximum output power conditions.

[4] Use 3, 8, 12, 25, 36 and 50 RB allocations, respectively, for 1.4, 3, 5, 10, 15 and 20 MHz channel bandwidths.

[5] A KDB inquiry should be submitted to determine the procedures required for testing UE Category 5 devices using 64QAM.

[6] If the maximum average conducted output power for a 1 RB allocation is > ½ dB higher than the 50% RB allocation, instead of using the highest SAR channel measured for QPSK and 50% RB allocation, measure SAR on the highest output power channel for the 1 RB allocation.

[7] If the maximum average conducted output power for 16QAM is more than ¼ dB higher than QPSK, apply the procedures for QPSK in 3) to test 16QAM.

[8] If the maximum average conducted output power for 16QAM with 50% RB allocation is > ½ dB higher than QPSK with 50% RB allocation, instead of using the highest SAR channel measured in QPSK measure SAR on the highest output power channel for 16QAM with 50% RB allocation.

I) If the SAR for a 1 RB configuration in B) is > 1.45 W/kg, test that 1 RB configuration on all channels (H, M, L).

5) For the other channel bandwidths used by the device within a LTE frequency band:

A) When the maximum average conducted output power of a smaller channel bandwidth is at least ½ dB lower than the maximum average conducted output power measured for the largest channel bandwidth, that smaller channel bandwidth does not need testing.

B) When the maximum average conducted output power for a smaller channel bandwidth is within ½ dB, higher or lower, of that measured for the highest channel bandwidth:

I) for each channel and RB configuration measured in 3) and 4)[10] with SAR > 1.45 W/kg, when applicable, measure SAR in the smaller channel bandwidth using that channel configuration and with the same number of RB allocation used for the largest channel bandwidth. For example, 50 RB in 10 MHz channel bandwidth does not apply to 5 MHz channel bandwidth; therefore, this cannot be tested in the smaller channel bandwidth. However, 50% RB allocation in 10 MHz channel bandwidth is equivalent to 100% RB allocation in 5 MHz channel bandwidth; therefore, the smaller channel bandwidth requires testing when the largest channel bandwidth SAR is > 1.45 W/kg.

a) When the SAR measured for an equivalent RB configuration in a smaller channel bandwidth in I) is > 1.45 W/kg, measured SAR on all channels (H, M, L) for that configuration in the smaller channel bandwidth.

C) When the maximum average conducted output power for a smaller channel bandwidth is > ½ dB higher than that measured for the largest channel bandwidth, apply the largest channel bandwidth procedures in 3) and 4) to test that smaller channel bandwidth.[11]

Typical head and body SAR test considerations for LTE handsets supporting simultaneously voice/data transmissions:

1) Test the standalone SAR of individual transmitters and transmitting antennas in the frequency bands, operating modes, device operating configurations and exposure conditions required by the applicable SAR measurement and KDB procedures. For example, voice and data modes in LTE, 1xRTT, WCDMA, GSM, EvDo, HSPA, GPRS/EDGE, WiMax, Wi-Fi, Bluetooth etc. for head (touch and tilt positions) and body-worn exposure conditions, antenna diversity configurations, handset flip or slide cover positions, modulations, channel bandwidths and resource allocations, such as data rate, zone type, symbol ratio/duty factor, data block size etc.

2) Identify the simultaneous voice/data transmission configurations and combinations for all applicable wireless operating modes, frequency bands and exposure conditions with respect to the parameters and configurations described in 1); typically in a tabulated format.

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[9] If the maximum average conducted output power for a 1 RB allocation is > ½ dB higher than the 50% RB allocation, instead of using the highest SAR channel measured for 16QAM and 50% RB measure SAR on the highest output power channel for the 1 RB allocation.

[10] Include the sub-sections in 3) and 4).

[11] See footnote 10.

3) Simultaneous transmission SAR test requirements must be considered independently for the *device and exposure configurations* required for the head & body, handset flip or slide positions and antenna diversity conditions etc.

   A) The exposure conditions for head and body are non-overlapping; therefore, these must be applied independently to determine the applicable SAR test reduction and exclusion requirements. For example, the highest SAR measured with the slide cover of a handset in the extended and retracted positions for the touch and tilt positions on the left and right side of the head for each transmitter/antenna may be applied to determine simultaneous transmission SAR test exclusion according to the sum of 1-g SAR or SAR to peak location separation ratio. However, these must not be mixed with body-worn SAR test configurations to determine SAR test exclusion. If applying the highest SAR in this manner does not allow SAR test exclusion, the individual *device and exposure configurations* should be considered separately for SAR test exclusion and reduction to minimize the number of volume scans required for simultaneous transmission. The configurations that qualify for test exclusion or reduction should be clearly identified in a tabulated format in the SAR report.

   B) When simultaneous transmission SAR measurement is required, the individual *device and exposure test configurations* must be measured and analyzed separately using volume scans to determine the 1-g SAR of overlapping SAR distributions.[12]

      I) When the number of simultaneous transmission combinations requiring volume scans is large due to multiple operating modes, frequency bands, device and exposure configurations for the higher output transmitters, a KDB inquiry is recommended after completing the standalone SAR measurements to determine if further test reduction might be possible or to confirm whether the proper simultaneous transmission SAR test configurations have been considered for testing.[13]

4) If every transmitter and antenna in the device can transmit at maximum output power in all combinations of simultaneous transmission configurations identified in 2) without the need to reduce maximum output power for SAR compliance, the simultaneous transmission SAR measurement requirements must be determined according to the maximum average conducted output power and SAR measured for each transmitter and antenna in each simultaneous transmission combination.

   A) The SAR test reduction, exclusion and volume scan procedures in KDB 648474 must be applied to the simultaneous transmission conditions identified in 2) to determine SAR test requirements.

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[12] The same device and antenna positions with respect to the head or flat phantom must be used for the volume scans to be processed correctly to determine 1-g SAR. Volume scan requirements may be implemented differently in different SAR measurement systems, including scan size and resolution requirements. A test lab must apply the proper volume scan test setups required by the SAR measurement system and in conjunction with the volume scan requirements in KDB 648474 to ensure test results are acceptable. A KDB inquiry is recommended before applying variations of the typical full size volume scan that requires all simultaneous transmitting antennas to be included in the scan. Details of the volume scan setup parameters, test configurations and 1-g SAR analysis must be described in the SAR report to support the test results.

[13] Since volume scans can be quite time-consuming, this enables the number of volume scans to be minimized with further considerations to situations where additional test reduction might be appropriate.

B) When simultaneous transmission SAR measurement is required, the KDB procedures required for testing each wireless technology must be applied to the volume scan measurements.

I) Except for evolving technologies with specific test difficulties, established cellphone technologies should be tested with an over-the-air connection using a communication test set.

II) Unlicensed or other emergent technologies may require a combination of test software and over-the-air connection to perform the SAR measurement.[14]

III) The measurement procedures for simultaneous transmission may be implemented differently in different SAR measurement systems;[15] the requirements of KDB 648474 must be fulfilled for the volume scans to be acceptable. The peak SAR locations identified in standalone SAR measurements of individual transmitters/antennas must be included in the volume scan. When it is unclear, a KDB inquiry should be submitted.

a) Transmitters and antennas operating in the same frequency band are typically measured in a single area/zoom scan test configuration according to KDB 648474. This may require multiple communication test sets to establish simultaneous over-the-air connections.

b) Transmitters and antennas that operate in different frequency bands or those operate in the same frequency band but cannot be measured using a single area/zoom scan test configuration must be tested separately according to the volume scan procedures described in KDB 648474.

5) When the maximum output power of one or more transmitters or antennas must be reduced under certain simultaneous transmission conditions to satisfy SAR compliance, other equipment certification or operating requirements, the following must be considered:

A) Clear descriptions of the power reduction mechanisms implemented for the applicable wireless modes and operating configurations are necessary to determine the SAR test configurations required for different exposure conditions.

B) Based on the power reduction and operating requirements described in A), there must be supporting data to demonstrate that the power reduction mechanisms are operating reliably and consistently; for example, according to power measurements in the applicable simultaneous transmission and power reduction modes.

I) If applicable, the sensing conditions required to activate and deactivate power reduction, such as antenna or transmitter output conditions, user proximity etc. must be explained and verified.

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[14] A signal generator in conjunction with test software has been used to provide the synchronization necessary to establish the uplink signals required for testing some technologies when communication test sets are unavailable.

[15] Detailed requirements for volume scan measurement implementation are unavailable in current SAR measurement standards. While certain special SAR scan methods, interpolation and extrapolation techniques or algorithms are being explored by SAR system manufacturers and standards working groups to reduce measurement time, these techniques have not been standardized and may require further demonstration of reliability and consistency before they can be applied for typical use. A KDB inquiry must be submitted for case-by-case consideration to determine if certain methods may be applied on a limited basis to address specific measurement difficulties.

II) If the power reduction requires SAR scaling, applicable analyses and SAR measurement verifications are necessary to demonstrate that a conservative SAR margin is available for each *device and exposure configuration* in 2) to satisfy compliance.[16]

C) For the subset of simultaneous transmission configurations that do not require any transmitter to reduce output power, the procedures in 4) should be applied to determine SAR test reduction, exclusion and volume scan requirements.

D) For the subset of simultaneous transmission configurations that require one or more transmitters or antennas to reduce maximum output power for SAR compliance, other equipment certification or operating requirements, the results and analyses in B) must be applied to determine the maximum output power required for a transmitter or antenna operating in power reduction mode to perform SAR measurements.

I) Regardless of whether the power reduction is required for SAR or other requirements, the procedures in 4) A) and 4) B) should be applied to determine simultaneous transmission SAR test reduction, exclusion and measurement requirements according to the maximum output power allowed by the power reduction mechanisms implemented for the applicable transmitter and antenna configurations. For purpose of determining SAR test exclusion for simultaneous transmission in power reduction modes, the SAR of a transmitter or antenna tested at the maximum output power in standalone mode may be applied to determine SAR exclusion requirements. When volume scan measurement is required, the maximum output power in each power reduction mode must be used for the SAR measurement.

a) Transmitters and antennas operate in different frequency bands must be tested independently, one at a time, according to the required volume scan SAR procedures. Some test configurations may require special test mode/code, test software/firmware or a combination of these to enable power reduction to operate correctly in the required operating mode for SAR testing. Since only one transmitter/antenna is allowed to transmit during the volume scan SAR measurement, other transmitters operating in different frequency bands that normally transmit simultaneously must be disabled during the SAR measurement for the SAR probe calibration to apply. Therefore, the device is unable to adjust the maximum output power of one transmitter according to the output conditions of the other transmitter(s). The procedures applied to manually simulate the power reduction conditions required to perform SAR measurements must be clearly described in the SAR report

b) The detailed procedures and requirements used to establish these special test operating modes must be clearly explained in the SAR report. A separate KDB inquiry may be necessary and is recommended to determine if a specific test setup is acceptable for measuring the required configurations in power reduction modes. While certain specific confidential details are typically not needed to describe the test setup, the general test configurations must be clearly explained to support the test results in the SAR report.

[16] The scaling of SAR vs. power generally varies from transmitter to transmitter due to SAR distribution and design differences. The power reduction provided by one transmitter may not necessarily provide the same magnitude of SAR reduction for another transmitter operating within the device; therefore, may not support the power in one transmitter to be increased by an equal amount reduced in another transmitter; especially when different frequency bands are considered.

6) When simultaneous transmission SAR measurement is required by 4) or 5), use the highest SAR channel measured in the standalone mode in 1) for each wireless mode, frequency band, operating and exposure conditions to perform volume scans. The same *device operating configuration and exposure conditions* must be used in volume scans for SAR distributions to be summed correctly to determine the 1-g SAR.[17]

   A) A KDB inquiry should be submitted when it is unclear if certain *device operating configuration and exposure conditions* may be considered collectively for determining simultaneous transmission SAR measurement requirements.

   B) If any of the measured volume scan SAR is > 1.45 W/kg, submit a laboratory testing KDB inquiry with descriptions of the test setups and all available test results to determine whether additional configurations might need testing to ensure compliance.[18]

[17] See footnote 12.

[18] See footnote 13.